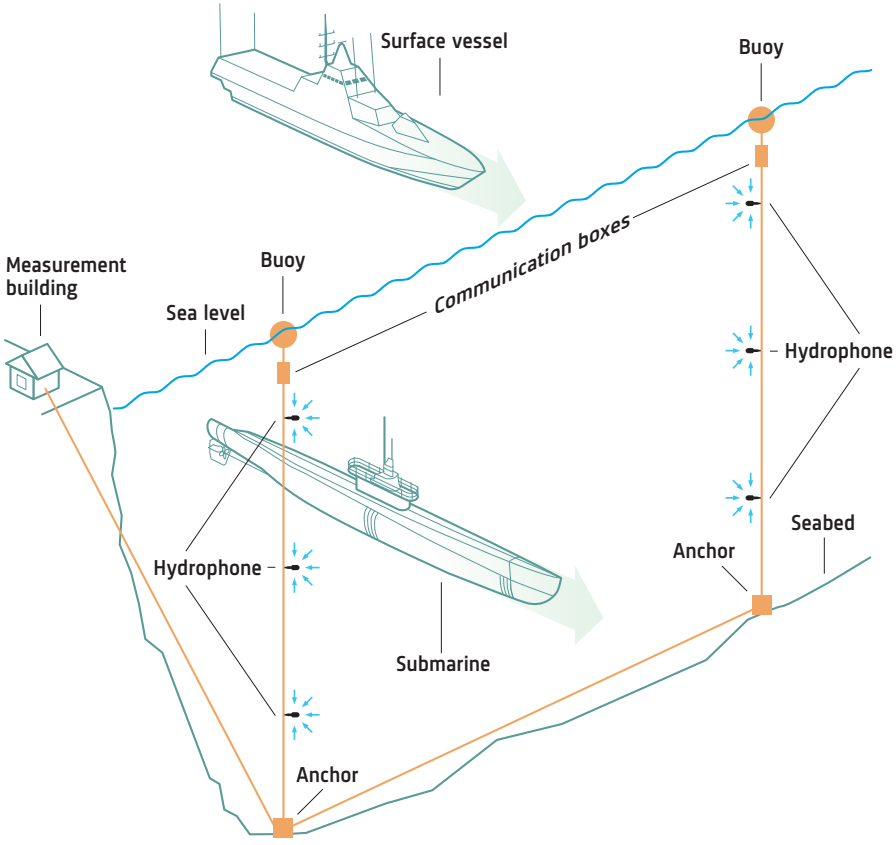
Brüel & Kjær
BEYOND MEASURE

THE ROYAL NORWEGIAN NAVY UNDERWATER ACOUSTIC NOISE MEASUREMENT OF VESSELS

A vessel's acoustic signature provides recognition to friends and enemies alike. The acoustic range at Heggernes in Norway measures all types of NATO naval vessels, and is one of only a few in the world. New and refitted vessels are measured to NATO standards, to identify changes and deviations from specified noise levels. Reliability and accuracy are essential for their hydrophones and customized software.



CHALLENGE

Characterize the acoustic signature of NATO submarines and surface ships in operation

SOLUTION

Durable underwater acoustic ranging system including hydrophones, analysis equipment and customized software

RESULTS

- Vessels characterized and compared to design specifications with unquestionable data accuracy
- Minimal hydrophone recalibration requirements

The control building for the underwater acoustic range at Heggernes. The radar system has a range of 25 nm.

BACKGROUND

Early in the 1990s, the navies of Germany, Norway and The Netherlands entered into a cooperation agreement to establish an underwater acoustic range. Several locations were considered according to a number of criteria. Heggernes near Bergen was chosen and the station commenced operating in 1994.

The Material Command of The Royal Norwegian Navy has overall responsibility for the operation and maintenance of the station. It also has responsibility for testing the vessels of the Royal Danish and Royal Norwegian navies. The Dutch and German navies are responsible for carrying out their own acoustic ranging. The responsible authority in The Netherlands is the Naval Electronics and Optics Establishment (MEOB). The Wehrtechnische Dienststelle für Schiffe und Mainewaffen (WTD71) is responsible for German testing. Separate computers, with removable hard disks, are used by each country. Postprocessing of data on Norwegian vessels is made at Heggernes, while the data on German and Dutch vessels is made in their respective countries. Data is archived on magnetic tape. The naval vessels of other countries, and some civilan vessels are also occasionally tested. This is dependent upon the facilities being available, and the approval of the testing. A committee comprising representatives of The Defence Ministries of Germany, The Netherlands and Norway meets annually to set out the principle guidelines for operation of the station.

ACOUSTIC RANGING

The purpose of acoustic ranging is to measure the noise generated by vessels at various speeds. A vessel's acoustic signature is most important for its function in military operations. Noise ranging is performed, for example, after major maintenance work, modifications or the installation of new equipment, in order to reveal any changes in the noise levels of the vessel. New vessels are measured to ensure that the noise levels are within the limits stipulated in the building specifications, and that they are in accordance with NATO requirements. It is also important to check

The range area. A number of hydrophones are located in the dynamic and static ranges

The view from the office window! The ferry M/S Nordlys passing the Heggernes range

that new vessels of the same class have nearly identical acoustic signatures. Both the static and dynamic ranging of vessels are carried out at Heggernes. Lt. Cdr. Harald Tholo, Royal Norwegian Navy, explains, "It's a very great advantage to have a 400 m deep fjord. There are less reflections from the seabed and therefore Heggernes is an ideal site for our work."

STATIC RANGING

Static ranging is carried out by mooring the vessel between three buoys in the static range. Two hydrophones (underwater acoustic transducers) are attached to the seabed (about 50 m below the surface), one on each side of the vessel. The water is deep enough to allow submarines to submerge while moored. The hydrophones are connected to the range house by 2 000 metre cables. A telephone line is also installed for voice communication with the moored vessel. To perform the tests, the various units on board the vessel (pumps, blowers, fans, generators, air conditioning, etc.) are started in turn and the noise they produce is measured.

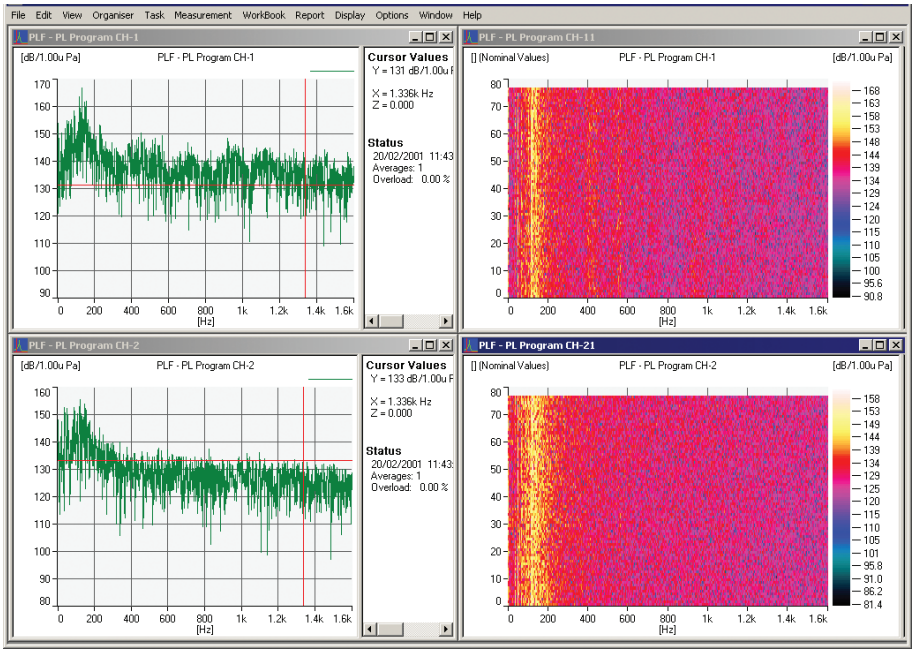
DYNAMIC RANGING

Dynamic ranging is carried out by means of the vessel following a particular course. The noise from the vessel is analysed when it passes a specific point on the course, referred to as the closest point of approach (CPA). Five hydrophones are used – one is anchored to the seabed; the other four are in banks of two and their height below the surface can be altered as required using a hydraulic winch. For surface vessels the upper pair of hydrophones are set to a depth of about 20 m below the surface while the lower hydrophones are at about 90 meters. The hydrophones are connected to the range house by 1 500 metre long cables. Lt. Cdr. Tholo explains, "The signal-to-noise ratio decreases if the hydrophones are too far away from the noise source and the background noise must be at least 6 dB below the source." Although the dynamic test range is in "public" water, the Police and Coastguard ensure that other vessels are excluded from the area when testing takes place. It is important that the position of the vessel and any deviation relative to the positions of the measuring hydrophones are correct because loss of noise energy from the vessel to the hydrophones must be calculated in the analysis. Therefore, surface and underwater tracking systems have been installed which can determine the position of the vessel to be measured at any particular time. The GPS (Global Position System) can fix the position of a vessel with an accuracy of about 2 metres. The position of a submerged submarine is determined by sonar. Voice communication with the vessel is either by a secure digital radio link or, to submarines, by underwater telephone. These systems make it possible for the acoustic range to have continual control over the location of the vessel at all times.

> "WE ONLY CALIBRATE THE HYDROPHONES ONCE A YEAR AS OUR EXPERIENCE SHOWS THAT THEY DO NOT GO OUT OF SPECIFICATION."
>
> *Erling Minde, Royal Norwegian Navy*

Left to right: Lt. Cdr. Harald Tholo, Kjell Johansen, Erling Minde

A typical PULSE™ display showing 2- channel FFT analysis graphs and contour plots



"WE CHOSE BRÜEL & KJÆR BECAUSE THEIR PRODUCTS ARE ACCURATE, EASY TO HANDLE AND THE COMPANY HAS AN EXCELLENT REPUTATION. WE GET EXCELLENT SUPPORT, SERVICE AND TRAINING."

Lt. Cdr. Harald Tholo, Royal Norwegian Navy

HIGHLY TRAINED EXPERTS

The permanent staff of the Heggernes range have unique experience and training in underwater acoustics. Lt. Cdr. Harald Tholo has a degree in hydroacoustics. He continued his studies at the Royal Norwegian Naval Academy and joined the Navy in 1985. Kjell Johnsen is an engineer and specialises in acoustics and sonar. He joined The Royal Norwegian Navy in 1988. Erling Minde is an acoustic measurement specialist and joined The Royal Norwegian Navy in 1986.

EQUIPMENT

The range house at Heggernes has a wide variety of Brüel & Kjær equipment including:

- 4-channel PULSE™ Multi-analyzer
- Types 2131 and 2133 Analyzers
- Type 2720 Power Amplifiers
- Types 2306 and 2307 Level Recorders
- Type 2625 Vibration Pick-up Amplifier
- Type 2628 LF Charge Amplifiers
- Type 2650 Precision Conditioning Amplifiers
- Type 2033 FFT Analyzer
- Type 5619 Channel Selector
- Sound Level Meters

Brüel & Kjær hydrophones are also used at the Royal Norwegian Navy's base at Bergen. The Heggernes facility boasts a large amount of the latest "hightech" equipment. The height of the hydrophones is controlled using the SIMRAD hydrophone system. Kjell Johansen says, "Our latest acquisition is 31 foot twin-screw launch which we will use to visit the vessels being tested."

MEASUREMENTS

Lt. Cdr. Harald Tholo explains, "We follow the established NATO Standards for acoustic ranging." Kjell Johansen says, "The PULSE™ software has been customised and the data collection process is highly automated. Frequency corrections for accurate calibration values of the hydrophones and distance correction calculations are made." The vessel being tested normally makes four test-runs – two east and two west. The results from the four runs are correlated. The data is posted back into the PULSE™ system. Kjell continues, "We use FFT analysis extensively and all the computers run under Windows NT®". Erling adds, "We calibrate the cables and preamplifiers before and after every test run. The

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>
> *Kjell Johnsen, Royal Norwegian Navy*

calibration is made using sine waves, and both white and pink noise. He continues, "We only calibrate the hydrophones once a year as our experience shows that they do not go out of specification." Reports are made in a standard military format using Microsoft® Word.

Accurate

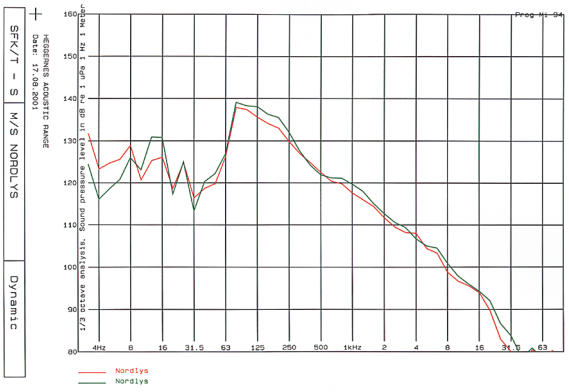
Lt. Cdr. Harald Tholo explains, "We chose Brüel & Kjær because their products are accurate, easy to handle and the company has an excellent reputation. We get excellent support, service and training." Kjell adds, "We are often in discussions with shipbuilders when we measure against the design specifications. When we tell them that we use Brüel & Kjær, there are no discussions concerning the accuracy of the data."

A PRACTICAL EXAMPLE

Much of the work carried out on naval vessels at the Heggernes range is secret. However, other ships pass the range and the ferry M/S Nordlys (11 200 tonnes, built in 1994) is a frequent visitor. To illustrate one aspect of the use of the underwater noise measurement system, the ship's noise signature was monitored using the submerged hydrophones on the dynamic range and fed, via conditioning amplifiers, into two channels of the Type 2133 analyzer. The program reads the data once per second and makes an average of the spectra. From this, a plot of the 1/3-octave analysis can be made, as shown in the illustration. On the x- axis the graph displays the acoustic frequencies generated by each of the ship's two propellers. The y- axis shows the sound pressure level in decibels related to 1µPa and corrected for bandwidth to 1Hz. A printed copy of the graph can be made displaying the spectra as a level function of frequency.

KEY FACTS

- Early in the 1990s, the navies of Germany, Norway and The Netherlands entered into a cooperation agreement to establish an underwater acoustic range
- The acoustic range at Heggernes, near Bergen, is used for measuring noise from all types of NATO naval vessels
- Acoustic ranging is used to measure the noise generated by vessels at various speeds
- The permanent staff at the Heggernes range are a highly trained team of experts
- The acoustic range uses a wide variety of Brüel & Kjær products including PULSE™, other multi-analyzers, customised software, power and conditioning amplifiers, sound level meters and transducers
- FFT analysis is used extensively
- The Royal Norwegian Navy chose Brüel & Kjær because their products are reliable, accurate, easy to handle and the company has an excellent reputation
- The Royal Norwegian Navy get excellent support, service and training



The graph shows the underwater acoustic frequencies generated by the ship's two propellers plotted against the sound pressure level in dB

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